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Analysis of bevameter/ regolith interaction mechanics using the COUPi discrete element method

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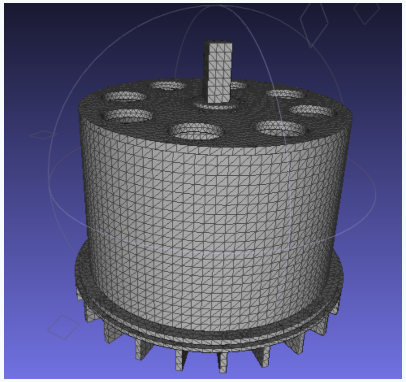
Introduction

- Bevameter technique was developed to measure terrain mechanical properties for the study of vehicle mobility
- Bevameter test consists of penetration test to measure normal loads and shear test to determine shear loads exerted by vehicle.
- Bevameter area size need to be the size of the wheel or track. DEM analysis can take data from one size and simulate bevameter performance for a different size.



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COUPi DEM

- COUPi is a discrete element method model developed as part of a NASA Lunar Science Institute project
- It can model interactions between particles of different shapes including polyhedra and machines
- The model has a computational "core" and "scenario" scripts allowing to build new tests and extend the model

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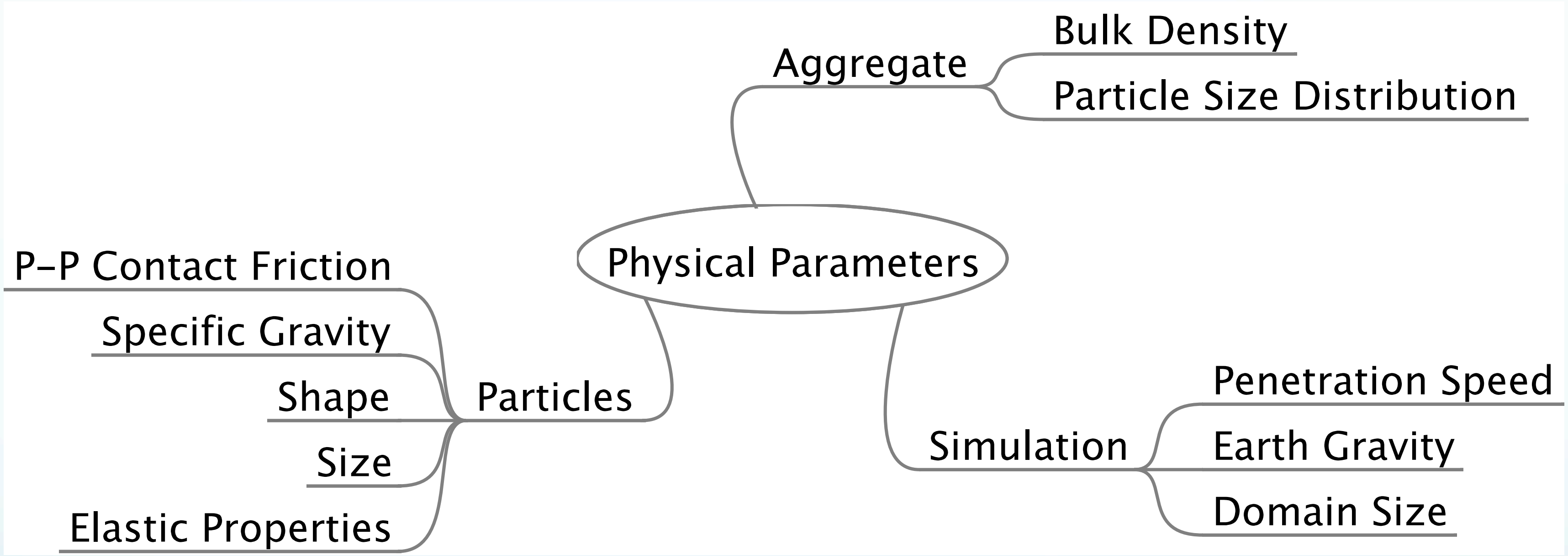
Physical Controlling Parameters



COUPi Bevameter Tests

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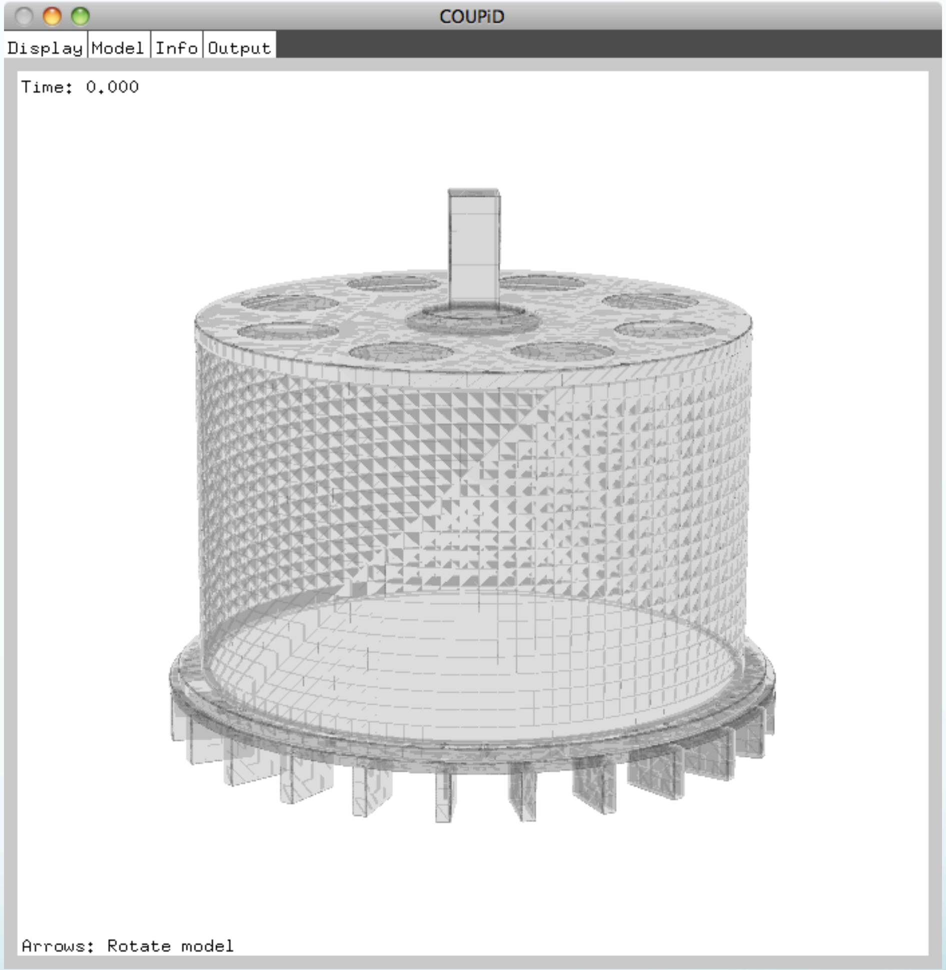
- Import the modeled bevameter shapes into the COUPi simulations using the CAD function.
- Compare measured results from laboratory bevameter tests to COUPi simulation runs using similar material properties for the particles (GRC-1 lunar simulant) with varying bulk densities.
- Analyze the effects of containers of different size in the simulation results.

COUPi CAD Module

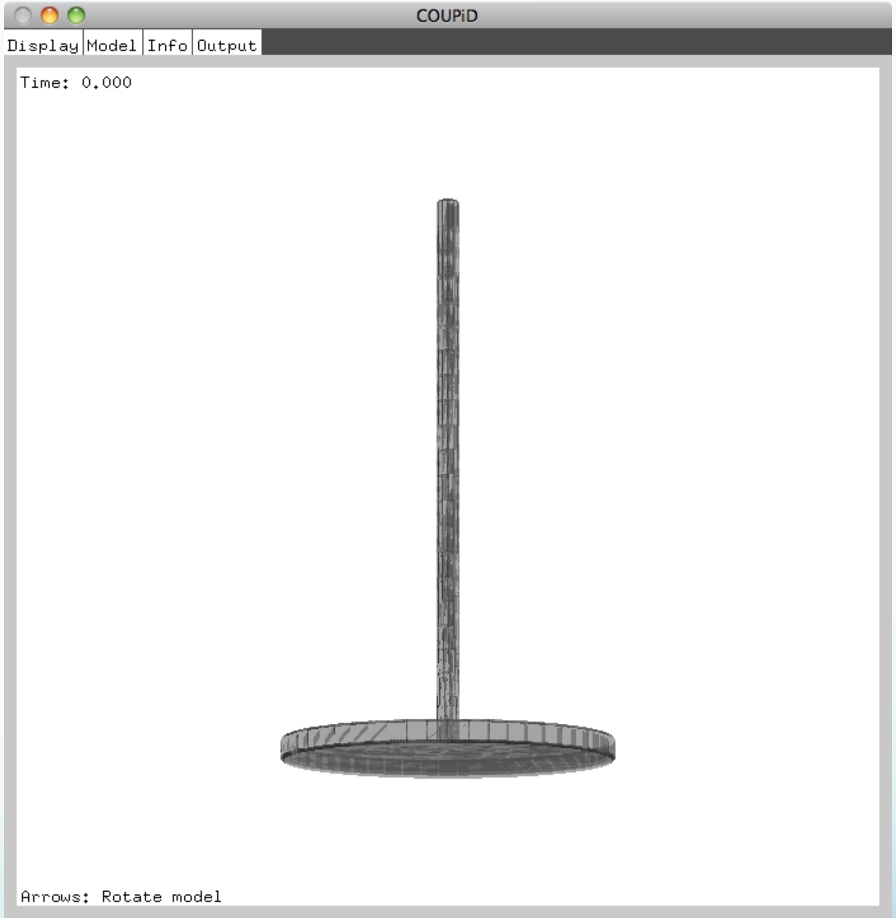
Image cup and shear ring from NASA Glenn



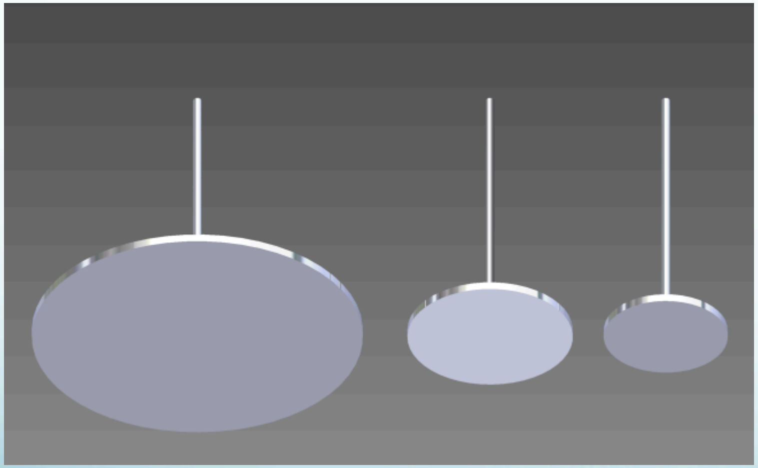
Cup and shear ring imported from manufacturer STEP model into COUPi

COUPi CAD Module

Image of flat plate from NASA Glenn



Flat plate imported into COUPi



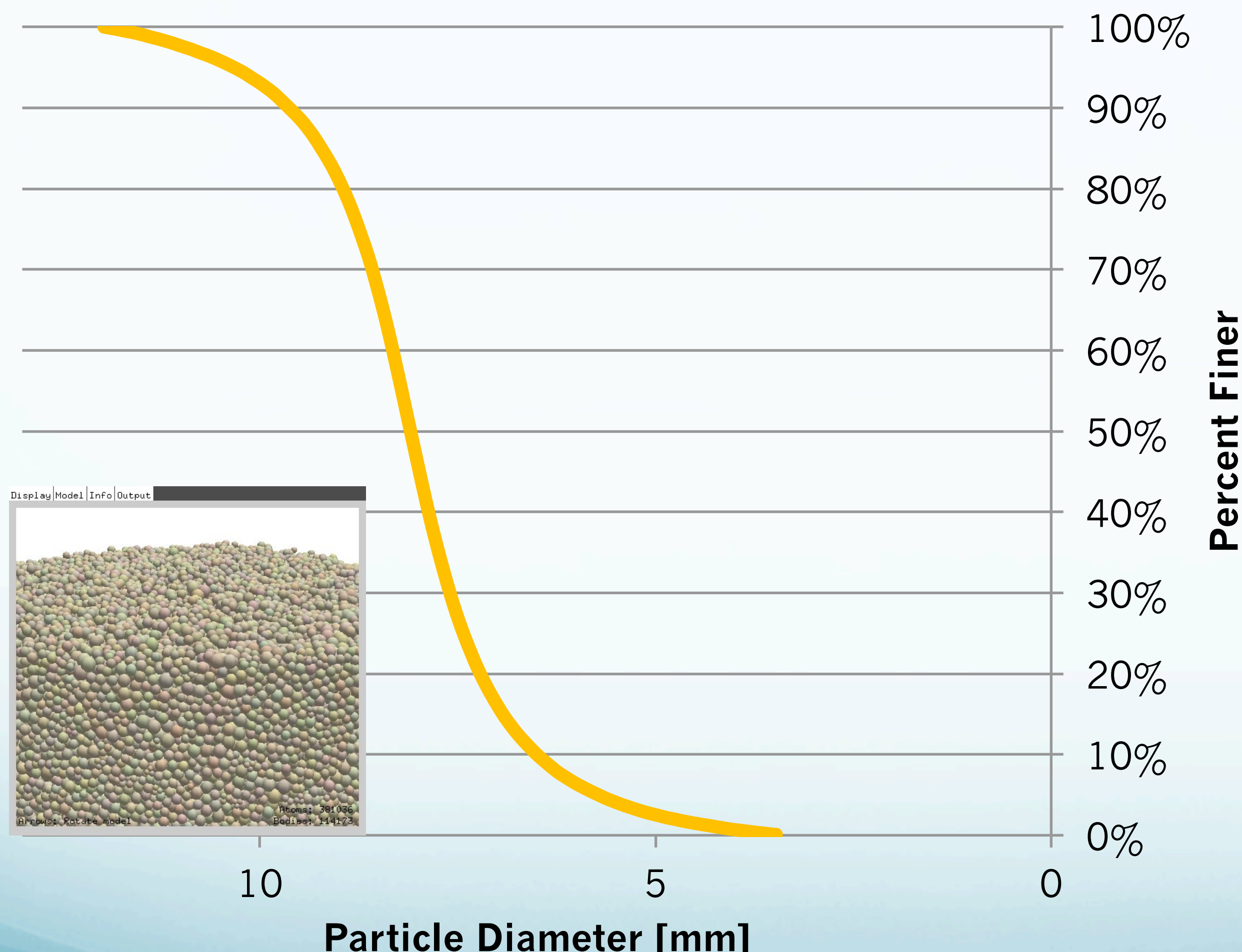
Flat plates modeled in Autodesk Inventor™

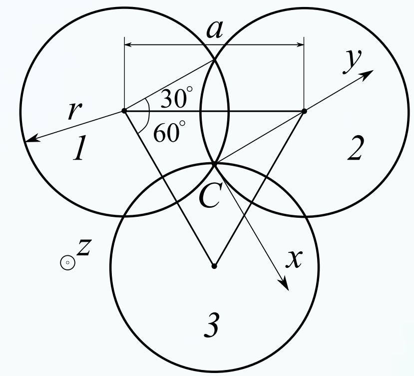
Bevameter setup

NASA Glenn bevameter

Particle Size Distribution

Log-normal PSD by spherical equivalent diameter





COUPi Sinkage Test Simulation

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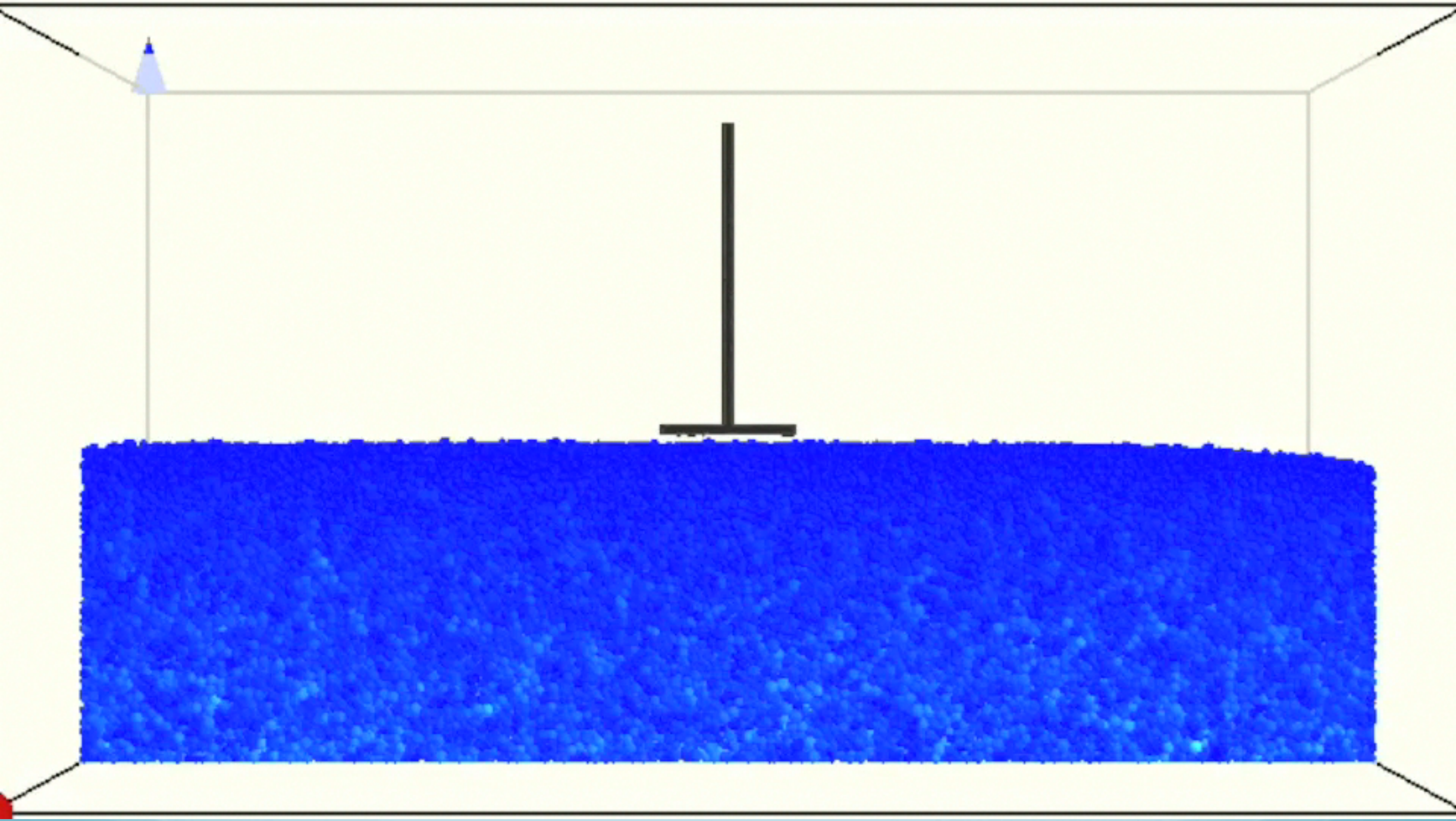

7.5 cm Plate Diameter – B.D. 1.70 – 2x Area

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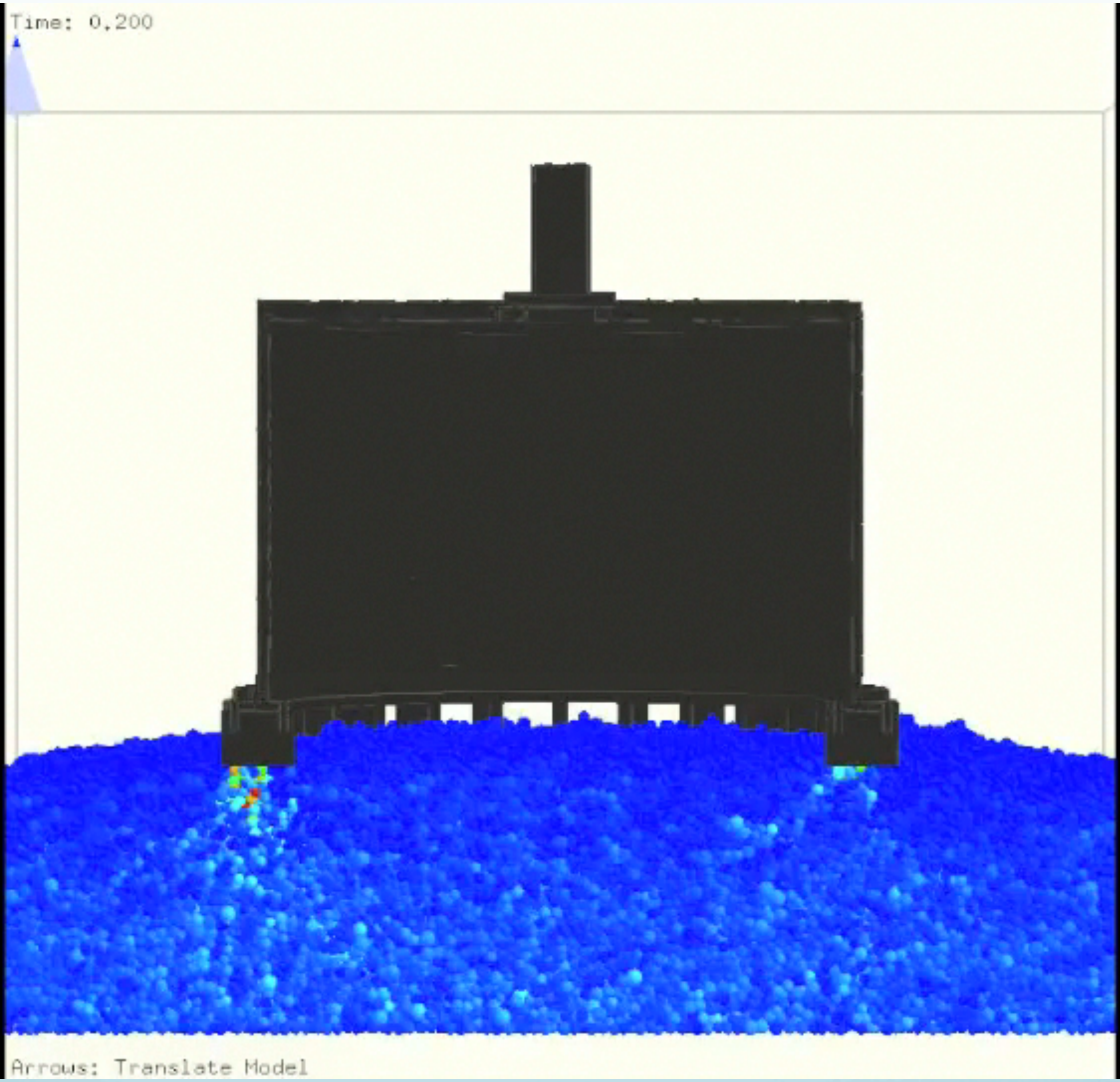
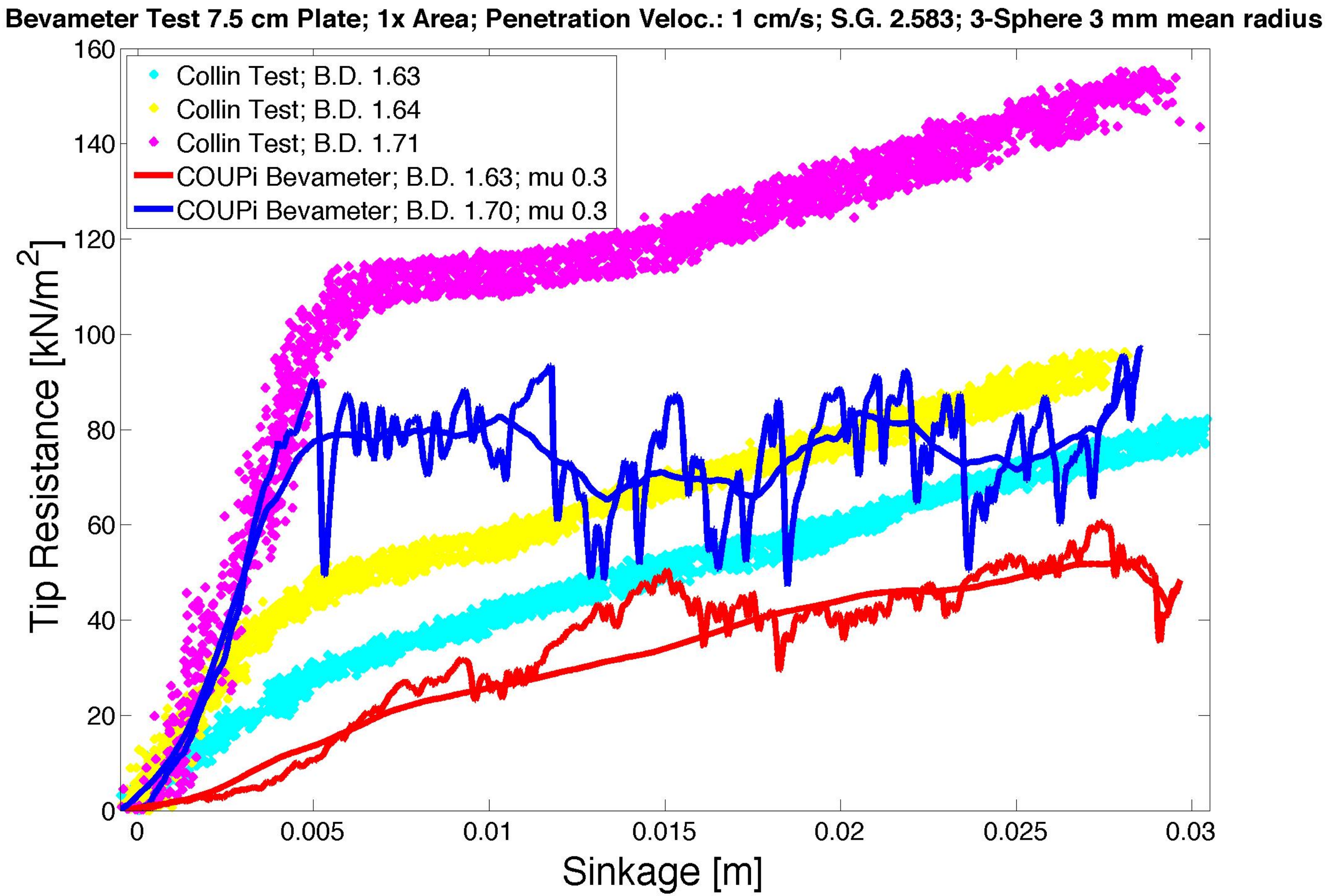
COUPi Shear Test Simulation

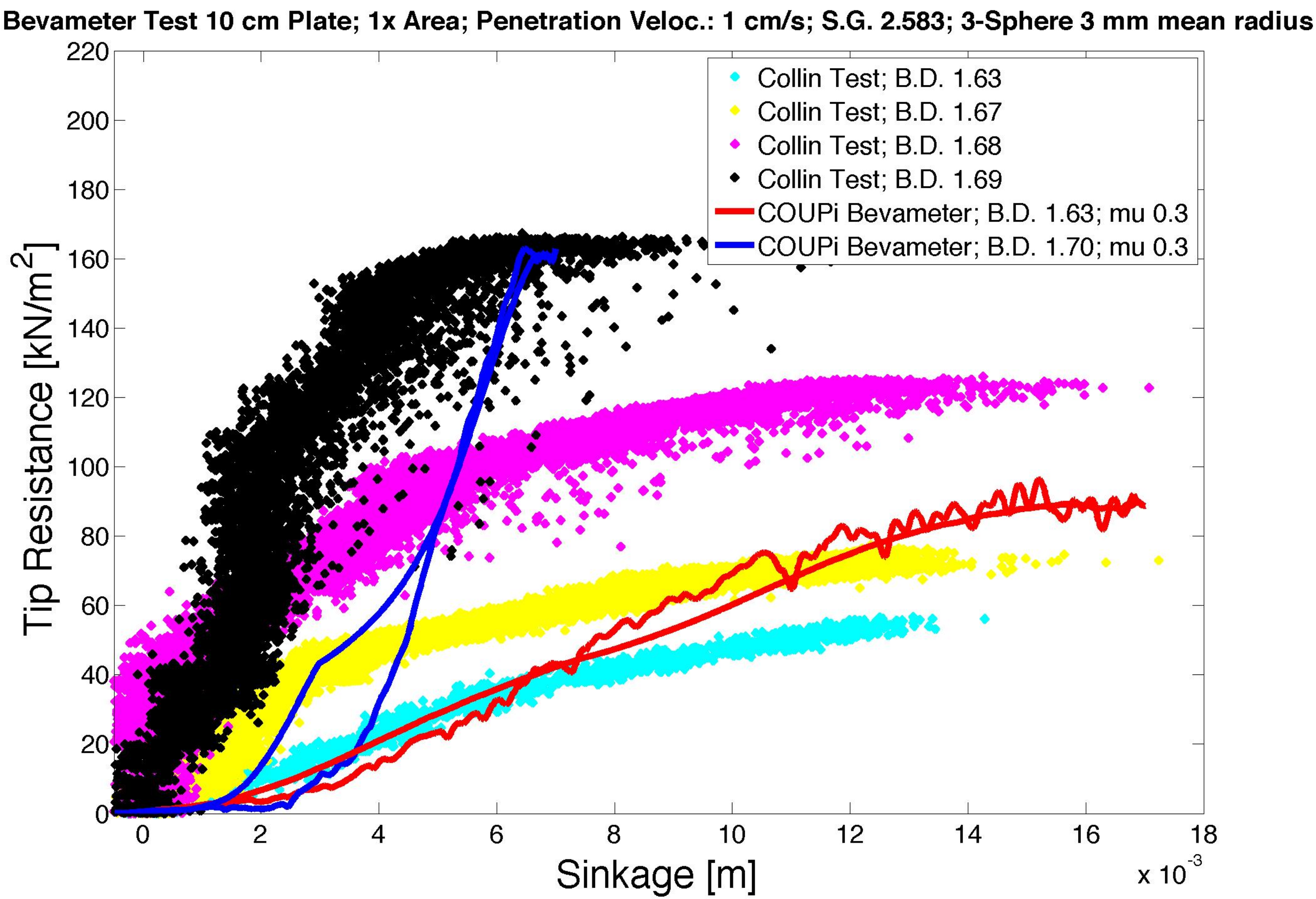


2.5 cm Grouser Height – B.D. 1.70 – 1x Area

Sinkage Test – 7.5 cm Plate Diameter – 1x Area



Sinkage Test – 10 cm Plate Diameter – 1x Area



Sinkage Test – 20 cm Plate Diameter – 2x Area

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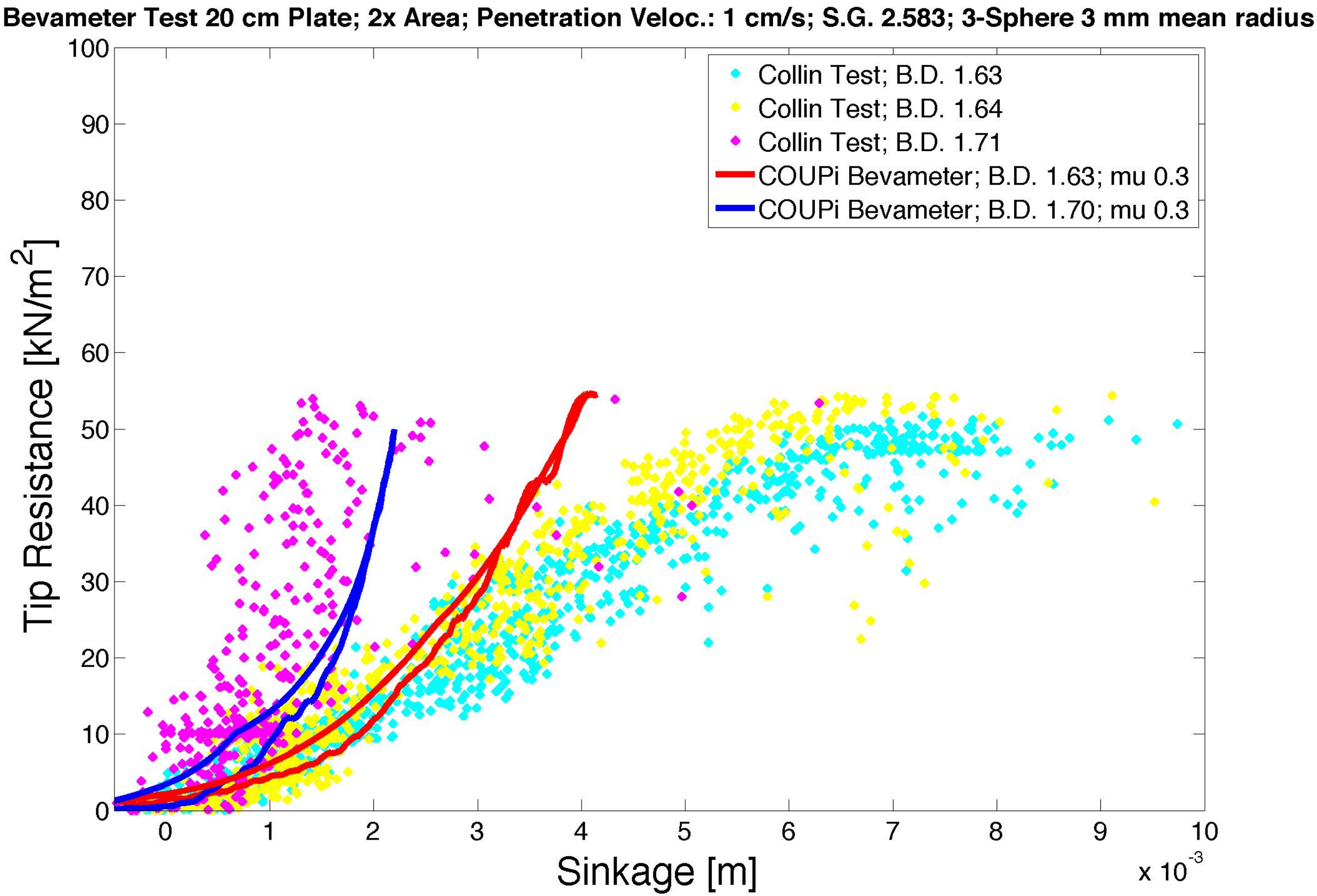

Shear Test – 2.5 cm Grouser Height – 5 kPa Load – 1x Area

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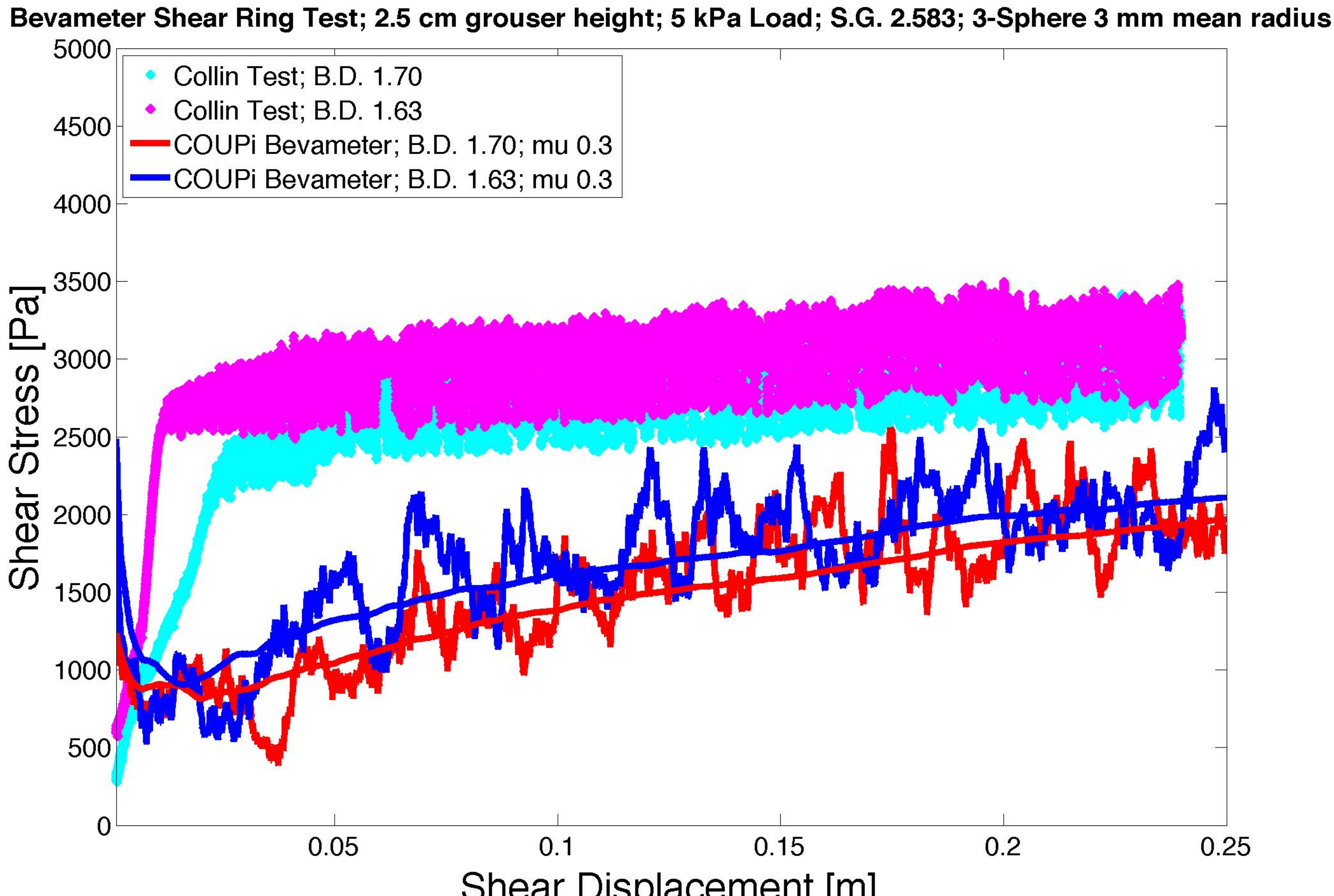
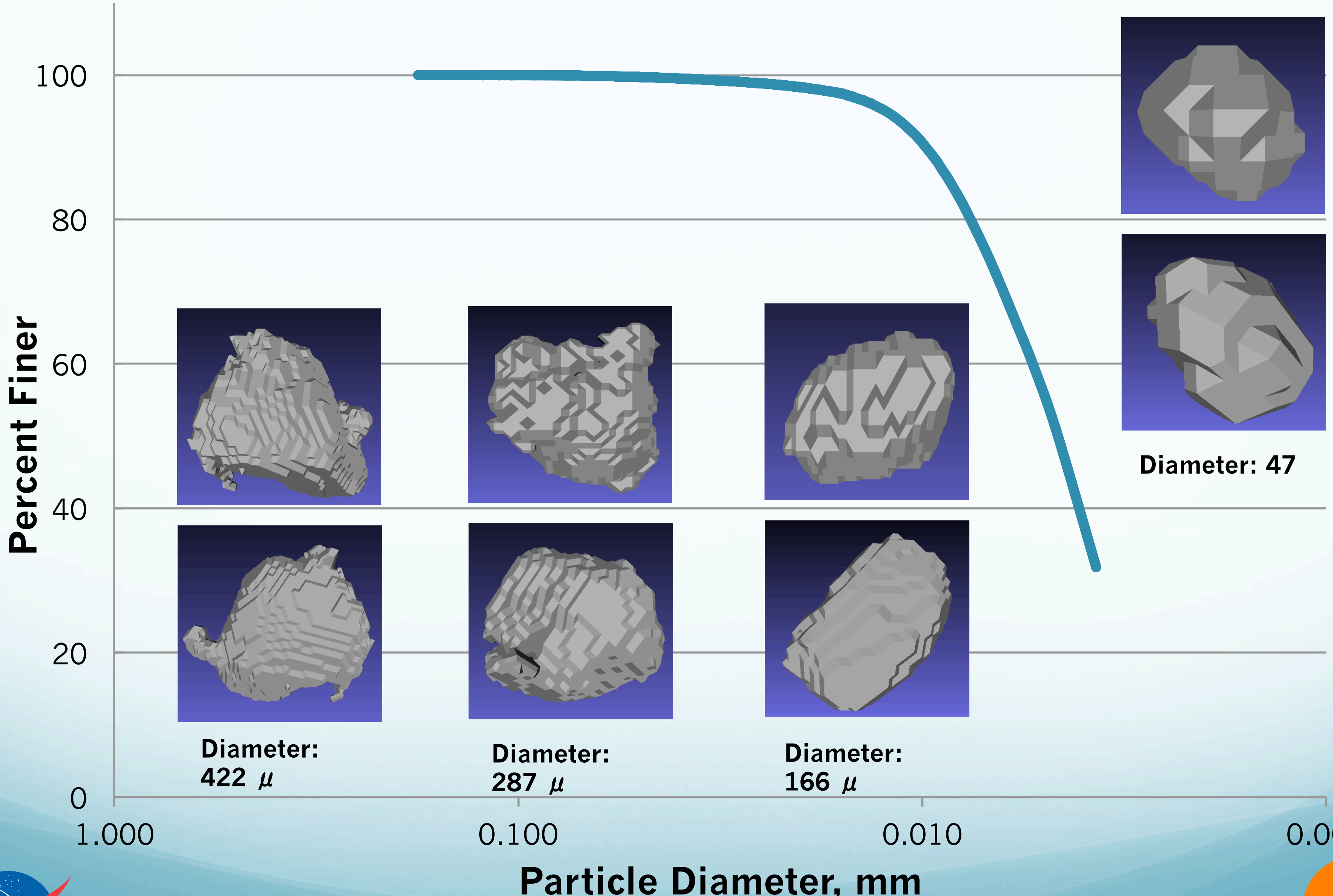


CT Scans of GRC-3



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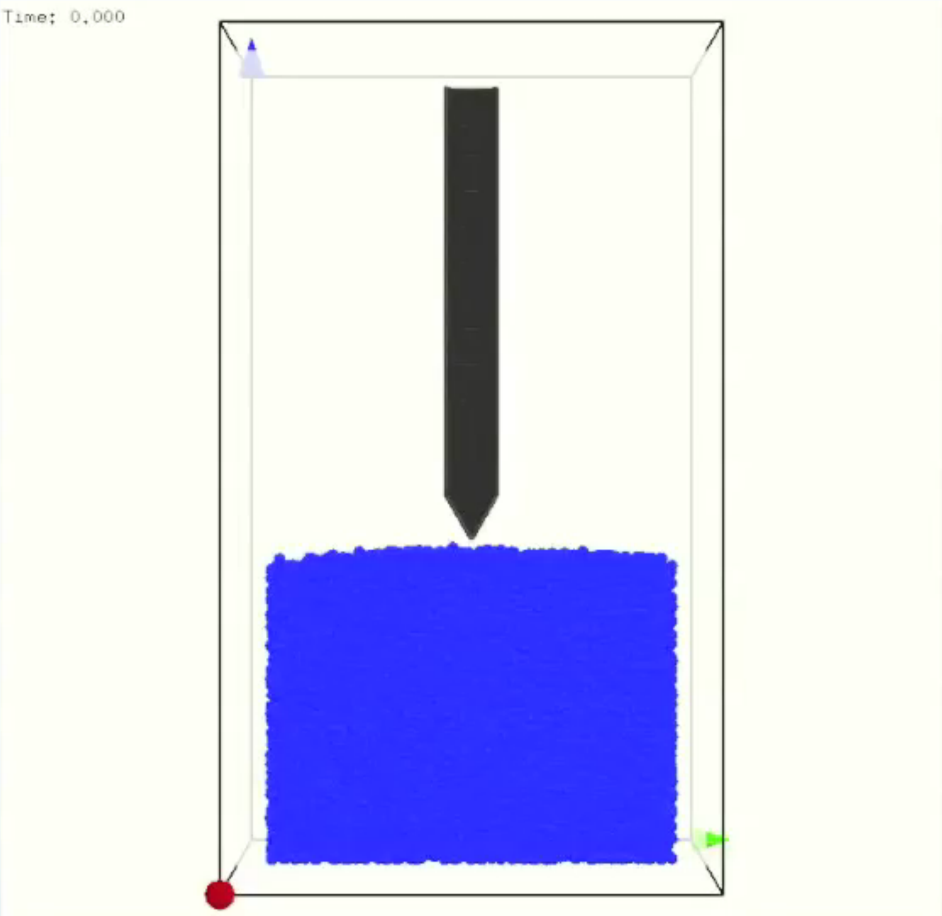
COUPi 3D CPT Simulation



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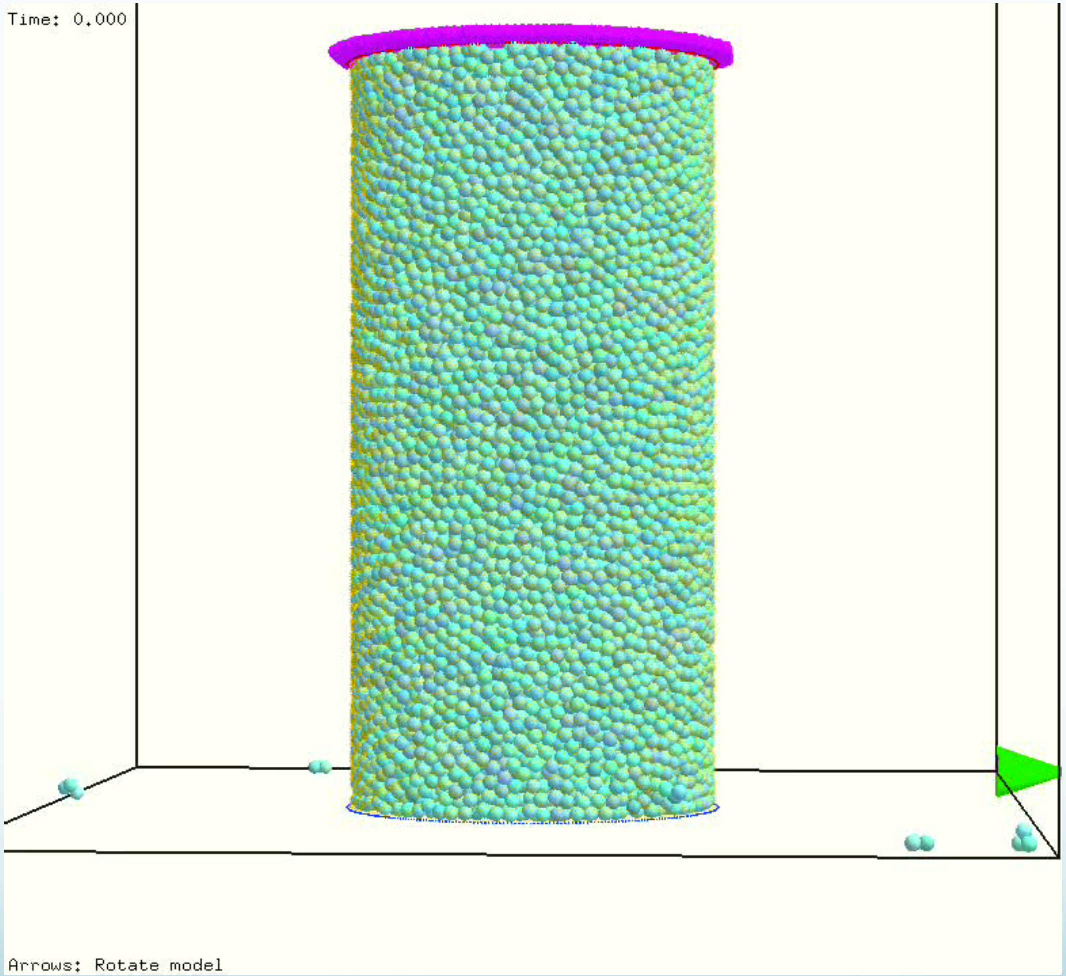
COUPi Triaxial Test Simulation



Conclusions

- Plate pressure and ring shear pressure results of simulations were generally in concordance or lower (in the case of the smaller flat plate) than laboratory tests, more runs are needed to calibrate simulation parameters.
- Faster penetration velocities produce higher oscillations in the simulations.
- Bigger soil containers minimized boundary effects, but computational resources usage increased greatly.
- More results needed for smaller size particles, different friction between particles, and shapes.